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THE DYNAMIC MECHANICAL ANALYSIS OF RUBBER BLENDS CONTAINING SINGLE WALL CARBON NANOTUBES

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ABSTRACT: The paper presents the study of mechanical parameters *E'*, *E''*, $tg\delta^l$, as functions of a temperature and frequency for rubber samples filled by *SWCNT* obtained by dynamic mechanical analyzer *(DMA)*. It shows an increase of both parts of the Young modulus, but on the other hand a decrease of $tg\delta^l$.

KEY WORDS: mechanical properties, rubber

1. INTRODUCTION

The measurements of dynamical properties of materials for tyres production play an important role in the construction and design of such products. The actual technology of tyre production uses various kinds of rubber, reinforced by steel or textile fibres. In order to understand the dynamical properties of a tyre as a whole, it is necessary to know the dynamic mechanical properties of various rubber compounds present in the tyre. These data are also inevitable for computational models used in a tyre design.

Technological process of a production of carbon nanotubes (*CNT*) is relatively well understood [1,2]. The physical structure and properties of carbon allotropes are described in details for instance in the work [3]. *CNT* which is an allotrope of carbon black in the aspect of the structure is superior to carbon black in strength and its tensile stress is hundred times higher than steel's. In Table 1 we present chosen physical parameters for several known materials in comparison with *SWCNT* and *MWCNT*.

In this paper we present the study of rubber blend twins. Two mother samples of the rubber blend were prepared as twins. One with and the second one without *SWCNT* (marked as standard *S*).

The mechanical properties *E'*, *E''* and $tg\delta$ of investigated twins were measured by a *DMA* analyzer in the large frequency and temperature range.

Tab. 1: Mechanical properties of different materials in comparison to CNT [3]

Material	**Young modulus (GPa)**	**Tensile strength (GPa)**	**Density (g/cm³)**
SWCNT	1054	150	1.4
MWCNT	1200	150	2.6
Steel	208	0.4	7.8
Epoxy	3.5	0.005	1.25
Wood	16	0.008	0.6

2. EXPERIMENTAL PROCEDURE

Rubber blends were mixed in two steps. In the first step, we started with mixing natural rubber, then we successively added *ZnO*, carbon black (*N660 Cabot*) and finally sonicated *SWCNT* in the oil (or oil only in the case of the standard sample). In the second step, sulfur, as a vulcanization agent, was added to the mixture. The temperature of *Brabender plasti-corder PLV 151* chamber was maintained at *80 °C*. The vulcanization temperature was *150 °C*. Four different samples were cut out from a different part of the same mother sample to test the sample homogeneity.

Mechanical properties of blends were tested by the analyzer *Perkin Elmer Pyris Diamond DMA*.

3. EXPERIMENTAL RESULTS AND DISCUSSION

Results of *DMA* were obtained for vulcanized samples only. They show the decrease of all measured values E', E'' and $tg\delta^l$ vs. temperature and increase of E' and E'' vs. frequency as a result of Payn's effect. Rising of E' between twins (at the beginning of the temperature dependence) is approximately *26 %* and it is caused by the presence of *SWCNT* (Fig. 1). On the other hand, the presence of *SWCNTs* does not substantially influence the value of E'' (*it* slowly increases with the presence of *SWCNT*). The temperature dependence for lower frequency (*0.01 Hz*) is relatively flat (Fig. 2) in all temperature spans under investigation. On the other hand, it is possible to see its relatively strong frequency dependence.

$tg\delta^l$ was the third investigated parameter responsible for the energy dissipation in the sample (Fig. 3). From these results it is possible to conclude that *SWCNTs* suppress the value of $tg\delta^l$ of a rubber blend in such a way that the value of E'' rises slowly and E' increases strongly ($tg\delta^l = \frac{E''}{E'}$), in other words it means the increase of elastic properties of the blend.

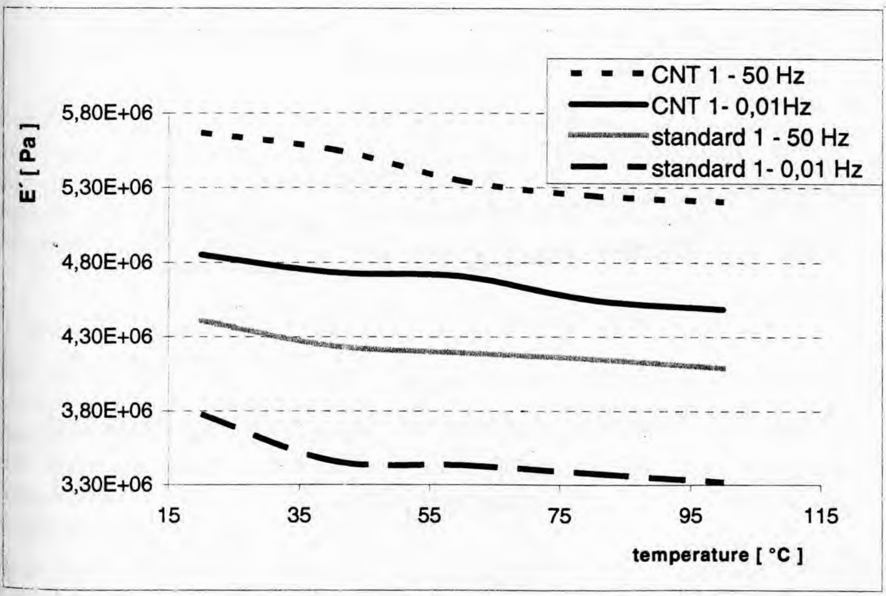

Fig. 1: The temperature dependence of the real part of the complex Young modulus for different frequencies

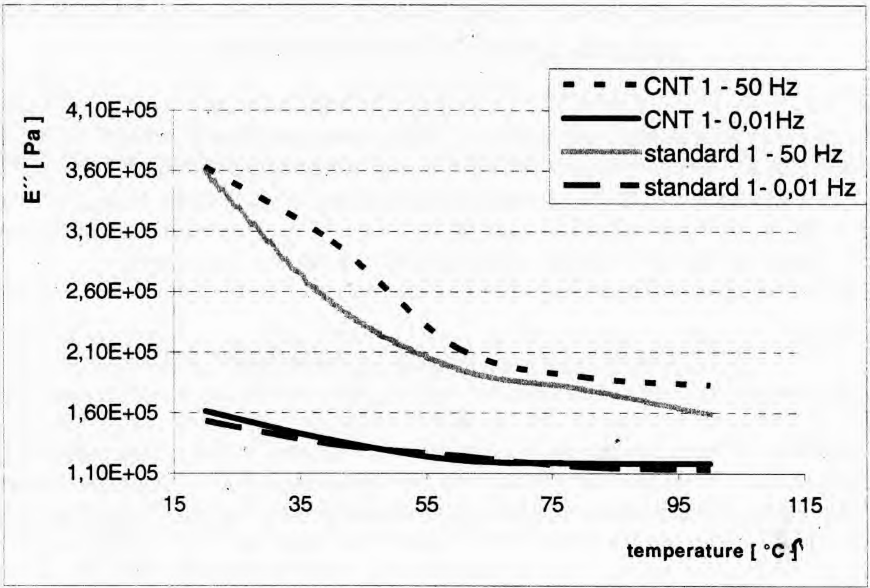

Fig. 2: The temperature dependence of the imaginary part of the complex Young modulus for different frequencies

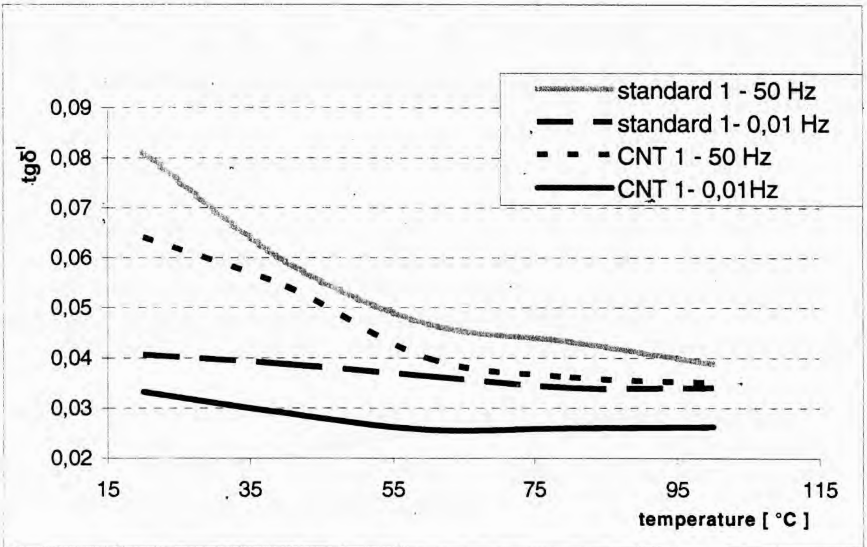

Fig. 3: The temperature dependence of the $tg\delta^{l}$ for different frequencies

4. REFERENCES

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